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ABSTRACT:

A hydrostatic speaker includes an oscillator (4), a partition diaphragm (5) disposed in the oscillator (4) to divide the oscillator (4) into two chambers (6, 7), at least one (6) of which chambers (6, 7) seves as a fluid chamber to cause the partition diaphragm (5) to vibrate in response to external signals from a source (12), an acoustic sound radiation core (1) connected with the partition diaphragm (5) via a rod (9), a sensor (10) for detecting fluid pressure in the fluid chamber (6) and another sensor (11) for detecting a movement of the diaphragm (5). The hydrostatic speaker is provided with a speaker driver which includes a fluid pressure controller (14) connected to a pressure source (17) for controlling the fluid pressure in the fluid chamber (6), and a control amplifier (13) for controlling the fluid pressure controller (14) in accordance with the external signals. Signals detected by the pressure sensor (10) and the position sensor (11) are respectively input as feedback signals to the control amplifier (13) in order to improve controllability, to reduce noise due to pressure fluctuation in the pressure source (17), and to improve a neutral positioning of the diaphragm (5). The hydrostatic speaker can radiate super low-frequency sound, which has been considered difficult by conventional speakers.

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(54) Hydrostatic speaker and speaker driver.

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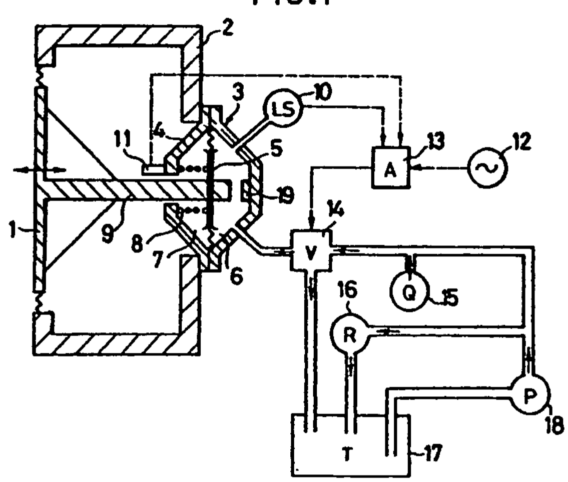
FIG.1



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HYDROSTATIC SPEAKER AND SPEAKER DRIVER

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates to an electric-acoustic transducer or a so-called speaker, which is a kind of acoustic equipment, and a speaker driver, more particularly to a speaker suitable for radiation of super low-frequency sound and a driver arrangement therefor.

Background Art

Generally, speakers used for acoustic radiation are dynamic speakers (DS) having a construction shown in Fig.4. In this type of speaker, a magnet M and a yoke Y are employed for forming a powerful magnetic field across a voice coil VC. When the alternating current is supplied to the voice coil VC, a core B connected to the voice coil VC starts vibrating, as indicated by an arrow, with the voice coil VC, thereby radiating a sound wave. The moving part of the dynamic speaker DS is held by a damper D, forming a single oscillation system as a whole.

The dynamic speaker DS generally possesses a frequency-sound pressure characteristic as shown in Fig.5, as long as an electric input is fixed. The speaker of this type therefore has been widely used as an acoustic equipment. As regards said characteristic, other types of speakers have a similar tendency.

However, as shown in Fig.5, an electric-acoustic conversion efficiency suddenly drops below the lowest resonance frequency fo and therefore the above-described dynamic speaker is unsuitable for use in the radiation of a super low-frequency sound below 50 Hz. As a method of lowering the lowest resonance frequency fo, increasing the weight of the oscillation system or reducing the strength of the damper could be taken into account. These measures, however, are likely to lower the electric-acoustic conversion efficiency and damping qualities. Furthermore, it is not necessarily fully effective if the electric input is increased in an attempt to compensate for the lowered efficiency because the exoergic of the voice coil increases.

SUMMARY OF THE INVENTION

One object of the present invention is to provide a speaker suitable for the radiation of super low-frequency sound, which has been considered difficult to perform because of the intrinsic characteristics of the speaker itself.

The speaker of the present invention is a hydro-static speaker of such a construction that the super low-frequency sound is radiated by the core driven by a fluid power driver. Specifically, an oscillator of the speaker is separated into two sections, front and rear, by a moving body, and one of two sections is used as a fluid pressure chamber for vibrating the movable body in accordance with external signals given to the moving body in the form of fluid pressure. The moving body is connected to the core for acoustic radiation, such that the low-frequency sound be radiated by the core. There may be provided, when necessary, a fluid pressure sensor for detecting the fluid pressure in the fluid pressure chamber, and a position sensor for detecting the position of the moving body and other parts which move with the moving body.

As another mode of the hydro-static speaker, both front and rear chambers of the oscillator are used as fluid pressure chambers to vibrate the aforesaid moving body in accordance with the external signals. Also, when necessary, there may be provided a differential pressure sensor for detecting a pressure difference between two fluid chambers and the above-mentioned position sensor.

The fluid-power driver for the speaker drives the core for the radiation of a low-frequency sound. The driving power source employed is a fluid pressure source, not an electromagnetic force source. The speaker of the present invention, therefore, can produce a high output for the radiation of a super low-frequency sound, that is, the speaker can serve as a low-sound speaker.

The fluid pressure in the fluid pressure chamber defined in a front or rear half of the oscillator varies with the signals, thereby vibrating the moving body. Vibrations thus produced are transmitted to the acoustic radiation core connected with the moving body, thereby radiating a low-frequency sound from the core. The moving body can be any type of the diaphragm, bellows and piston; and two fluid pressure chambers may be formed at the front and rear of the moving body, so that the moving body operates in accordance with a differential pressure between two chambers.

Since the speaker is operated by a fluid pressure, not by an electromagnetic force, and the fluid pressure system has intrinsically powerful driving and damping forces, the speaker can perform powerful sound radiation in a super low-frequency

range between approximately 0 Hz to 100 Hz. The frequency-sound pressure characteristics of the speaker are adjustable to low-pass characteristics under the power control. Thus, in combination with a conventional speaker, the speaker of the present invention can make a wider-band acoustic system.

The speaker driver of the present invention has a fluid pressure sensor (a differential pressure sensor in a case of a two-chamber type) which detects chamber pressures of the hydrostatic speaker, a fluid pressure controller connected to a fluid power source which controls the chamber pressures of the hydrostatic speaker, and a control amplifier which controls the pressure controller in accordance with signals: thus the hydrostatic speaker is of such a constitution that a signal from the fluid pressure sensor (the differential pressure sensor) is input to the control amplifier as a feedback signal in order to improve controllability as well as to prevent noise occurrence likely to be caused by pressure variation at a fluid power source. The detection signal from the fluid pressure sensor or the differential pressure sensor is fed back to the control amplifier, thereby eliminating pulsation within the low-frequency range.

Furthermore, the hydrostatic speaker of the above-mentioned constitution can be modified by providing a position sensor with the moving body or related parts operating together with the moving body. In this case, a detection signal from the position sensor is input as a feedback signal to the control amplifier in order to improve the response and the positioning of the moving body, i. e., to keep the moving body at the neutral position when no signal is present.

The fluid power source of the speaker driver preferably includes a pump which produces little pulsation, an accumulator, and a pressure regulator. Using the pump of little pulsation eliminates the pulsation of the fluid pressure, with the result that high-frequency noise components can be removed.

Furthermore, in the constitution of the speaker driver provided with the position sensors, because a detection signal from the position sensor is fed back as a feedback signal to the control amplifier in the form of displacement signal (or speed and acceleration signals if a differentiator is provided), the response characteristics of the speaker driver can be improved. In addition, the moving body can be kept at the neutral position at a no signal situation, and the drift of the fluid pressure (differential pressure) sensor can be cancelled.

Also, in the speaker driver, pulsation and, particularly, high-frequency pressure noises can be removed by using for example a screw pump as a pump for the fluid power source, in which little pulsation occurs, with an accumulator and a throttle mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a view showing one embodiment of a hydrostatic speaker and a speaker driver according to the present invention;

Fig.2 is a view showing another embodi ment of a fluid pressure driver of the hydrostatic speaker;

Fig.3 is a graph showing the frequency-sound pressure characteristics of the speaker according to the present invention;

Fig.4 schematically illustrates a conventional dynamic speaker; and

Fig.5 is a graph showing the frequency-sound pressure characteristics of the speaker of Fig.4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, a hydrostatic speaker and a speaker driver according to the present invention will be described with reference to the accompanying drawings.

The hydrostatic speaker and the speaker driver shown in Fig.1 are constituted of the following four sections. The first section comprises a core 1 and a cabinet 2 for efficient radiation of a low-frequency sound therefrom. The second section includes a hydraulic driver 3 and accessory sensors 10 and 11. The third section is an electric circuit section including a control amplifier 13. And the fourth section is a hydraulic circuit including a fluid pressure controller 14.

The core 1 mounted at the front of the cabinet 2 is made of a lightweight material having substantial strength, for example a carbon fiber molding, and so constructed as to vibrate as one body to output a specific sound. For the core 1, a flat board in Fig.1, any arbitrary shape, for example conical, may be chosen.

The hydraulic driver 3 mounted at the back of the cabinet 2 is of such a contruction that the interior of a robust oscillator is divided into two chambers, front and rear, by a partition diaphragm 5 which is a moving body disposed at the center thereof, and one chamber, that is, the rear chamber 6 in Fig.1, serves as a fluid pressure chamber. In the other chamber (front chamber) 7 is disposed a spring 8 working against the fluid pressure in the fluid pressure chamber 6. In the fluid pressure chamber 6 is provided a stopper 19 in order to protect the diaphragm 5 from excessive deformation when the fluid pressure therein is small.

The core 1 and the diaphragm 5 are connected

with each other by a rod 9 extending through the interior of the cabinet 2.

The hydrostatic speaker is provided with a fluid pressure sensor 10 which detects a pressure in the fluid pressure chamber 6 and a position sensor 11 which detects the movement of the connecting rod 9. Since the connecting rod 9 operates with the diaphragm 5 and the core 1, it is not necessarily required to locate the position sensor 11 in the vicinity of the connecting rod 9, but may be disposed in the vicinity of the diaphragm 5 or the core 1. Detection signals from the fluid pressure sensor 10 and the positon sensor 11 are sent to the control amplifer 13.

The control amplifer 13 controls a fluid pressure controller 14 in accordance with a signal input from a signal source 12. The fluid pressure controller 14 sends an outut singal to the hydraulic driver 3 to control the pressure in the fluid pressure chamber 6. The detection signals from the above-mentioned sensors 10 and 11 are additionally input into the control amplifier 13, which in turn changes the signal to be output to the fluid pressure controller 14 for the purpose of proper adjustment of the fluid pressure chamber pressure.

The fluid power source includes a pump 18, and employed as the pump is a type causing little pressure noises, for example a screw pump, in order to prevent a fluid power source ripple or to prevent unexpected sound due to the ripple. The pump supplies pressure with little pressure fluctuation to the fluid pressure controller 14 in cooperation with a pressure controller 16 and an accumulator 15.

Next, the operation of the speaker and the speaker driver of the above-mentioned constitution will be explained by referring to Fig.1.

The control amplifier 13 receives an electrical signal, which will be converted to an acoustic sound, from the signal source 12, and then converts it to an electric voltage or current suited to the fluid pressure controller 14 to control the controller 14. As the fluid pressure controlled by the fluid pressure controller 14 is supplied to the fluid pressure chamber 6 of the hydraulic driver 3, the diaphragm 5 moves right and left in accordance wiht signals from the signal source 12. The movement of the diaphragm 5 is transmitted to the core 1 through the connecting rod 9. The vibration of the core 1 changes air density, thereby producing compression waves. The compression waves are isolated from the diaphragm 5 by the cabinet 2 and the shell 4, so that there is little influence on the diaphragm 5.

The control amplifier 13, receiving an electrical singal for electro-acoustic conversion from the signal source 12, changes the signal to a variation of the electric voltage or current suitable for driving the controller 14. At the same time, the control amplifier 13 receives, as a correction signal, a pressure singal from the fluid pressure chamber 6 and a positional signal of the connecting rod 9 from the sensors 10 and 11 respectively. The fluid pressure detection signal from the fluid pressure sensor 10 is used not only to control the fluid pressure so that the fluid pressure properly follow the electrical signal but to control the fluid pressure of the hydraulic driver 3 so that unexpected pressure vibration in the pressure source be not radiated as a sound. Also, the signal from the position sensor 11 for detecting the connecting rod 9 is used to improve a neutral position holding function where no electric signal is present, and to improve a follow-up function as it is differentiated to speed and acceleration. The velocity and acceleration may be obtained by separator sensors.

It is desirable that the control amplifier be provided with a phase compensating circuit and a frequency characteristics compensating circuit in order to improve the characteristics of the hydrostatic speaker.

A fluid tank 17, the pump 18, the accumulator 15, the pressure regulator 16 and the fluid pressure controller 14, which have been established as existing arts, will not be explained herein, but it is imperative to employ those which are of low noise, little fluid pressure fluctuation, little temperature rise and high efficiency in order to accomplish the objects of the present invention. Also, the use of small, lightweight devices and a closed fluid circuit should be taken into account for easy movement of the hydrostatic speaker and the fluid devices.

Next, another embodiment of the present invention will be explained by referring to Fig.2.

The embodiment in Fig.2 shows a differential-pressure-type hydraulic driver having fluid pressure chambers 60 and 70 on both sides of the diaphragm 5. In this driver construction, the spring 8 and the stopper 19 shown in Fig.1 are not employed, but a bellows seal 20 is provided in their place to seal the fluid pressure chambers 60 and 70. The above-mentioned fluid pressure sensor 10 has been changed to a differential pressure sensor 21, and the fluid pressure controller 14 also has been replaced by a fluid pressure controller 22 which produces proper pressure difference between the pressure chambers 60 and 70.

Fig.3 shows the frequency-sound pressure characteristics of the fluid hydrostatic speaker of Fig.2. As indicated by a full line, it is understood that a sound in a super low-frequency range from nearly about 0 Hz to about 100 Hz is powerfully radiated. A dotted line indicates an extremely low-frequency range, for example 18 Hz or lower, to be artificially cut so that no excessive amplitude of frequency would occur.

In the case of a construction having a single fluid chamber and a spring which works against the fluid pressure as shown in Fig.1, the speaker has a resonance frequency given by the mass and spring and vibration system, but can be given similar characteristics as shown in Fig.2 by effecting an appropriate feedback control.

As compared with a conventional dynamic speaker having high-pass (high-range pass, low-range attenuation) frequency-sound pressure characteristics, the hydrostatic speaker of the present invention has low-pass (low-range pass, high-range attenuation) characteristics; therefore, it is possible to form a wide-band acoustic system by using the speaker in combination with the conventional speaker. Particularly, at an outdoor rock concert for instance, attenuation is commonly done in a low-frequency range of below about 80 Hz; however, since the hydrostatic speaker radiates an extremely low sound which the audience can feel as wind pressure, a much more powerful acoustic effect can be obtained when used at the outdoor music concerts.

When a hydraulic driver is used to produce a sound, a pressure variation in the fluid power source becomes a noise, spoiling the sound qualities. The hydraulic speaker of the above-described embodiment, however, can produce a clear sound without noises because it uses a low-speed screw pump for the pump 18 which hardly produces pulsation and the fluid pressure chamber pressure of the driver 3 or the pressure difference between two pressure chambers 60 and 70 is fed back.

In the above-mentioned two embodiments, the hydraulic driver for the speaker is of a diaphragm-type construction, but it is to be understood that the driver is not limited to the diaphragm type. It may be constructed of other types based on a similar principle, for instance a piston type, a bellows type, etc., as long as the expected functional effect are obtained.

Claims

1. A speaker for radiating acoustic sound in accordance with external signals supplied from a source (12) to the speaker, comprising a sound radiation core (1) and a cabinet (2) for the sound radiation core (1), **characterized** in that the core (1) is provided with a hydraulic driver (3) such that it (1) is driven by the hydraulic driver (3) and radiates a low-frequency sound.

2. A speaker having a core (1) for radiating acoustic sound in response to external signals supplied from a source (12) and a cabinet (2) for the core (1), **characterized** in that the speaker includes an oscillator (4) and a moving body (5), in that the oscillator (4) is divided into a front section (7) and a rear section (6) by the moving body (5), one section (6) serving as a fluid pressure chamber to vibrate the moving body (5) in accordance with the external signals, and in that the core (1) is connected with the moving body (5) such that it (1) radiates a low-frequency sound as the moving body (5) is vibrated by fluid pressure.

3. The speaker of claim 2, **characterized** in that a spring (8) is disposed in that section (7) of the oscillator (4) that does not serve as the pressure chamber such that it (8) pushes the moving body (5) against a fluid pressure in the other section (pressure chamber) (6), and that a stopper (19) is provided in the pressure chamber (6) for preventing excessive movement and deformation of the moving body (5) when no fluid pressure is present in the fluid pressure chamber (6).

4. The speaker of claim 2 or 3, **characterized** in that a fluid pressure sensor (10) is provided to detect a pressure in the fluid pressure chamber (6) or a pressure in a piping connected to the fluid pressure chamber (6).

5. The speaker of claim 2 or 3 or 4, **characterized** in that a position sensor (11) is provided to detect the position of the moving body (5) or of another element which moves with the moving body (5).

6. A speaker having a core (1) for radiating acoustic sound in response to external signals supplied from a source (12) and a cabinet (2) for the core (1), **characterized** in that the speaker includes an oscillator (4) and a moving body (5), in that the oscillator (4) is divided into a front section (70) and a rear section (60) by the moving body (5), both of which section (60, 70) serving as fluid pressure chambers to vibrate the moving body (5) in accordance with the differential pressure between said two sections (60, 70) responsive to the external signals, and in that the core (1) is connected with the moving body (5) such that it (1) radiates a low-frequency sound as the moving body (5) is vibrated by a fluid pressure difference.

7. The speaker of claim 6, **characterized** in that a differential pressure sensor (21) is provided to detect a pressure difference between said two pressure chambers (60, 70) or a pressure difference in a piping connected to said fluid pressure chambers (60, 70).

8. A speaker driver for the speaker of claim 4, **characterized** in that the speaker driver includes a fluid pressure controller (14) connected to a fluid power source (17) to control the fluid pressure of the fluid pressure chamber (6), and a control amplifier (13) for controlling said fluid pressure controller (14) in accordance with the external signals, and that a detection signal from the fluid pressure sensor (10) is supplied to said control amplifier (13)

as a feedback signal for improving its controllability and for preventing the noise due to variations in the fluid source (17) pressure.

9. A speaker driver for the speaker of claim 7, **characterized** in that the speaker includes a differential pressure-type fluid pressure controller (22) connected to a fluid power source (17) to control the differential pressure between two fluid pressure chambers (60, 70), and a control amplifier (13) for controlling the fluid pressure controller (22) in accordance with the external signals, and that a detection signal from the differential pressure sensor (21) is supplied to the control amplifier (13) as a feedback signal for improving its controllability and for preventing noise due to variations in the fluid source pressure.

10. The speaker driver of claim 8 or 9, **characterized** in that the speaker is provided with a position sensor (11) for detecting the position of said moving body (5) or of another element which moves with the moving body (5), and in that a detection signal from the position sensor (11) is supplied as a feedback signal to the control amplifier (13) in order to improve its response and the moving body neutral position holding function when no signal is present.

11. The speaker driver of claim 8, 9 or 10, **characterized** in that the fluid power source (17) is provided with a pump (18) which hardly produces pulsation, an accumulator (15) and a pressure controller (16).

12. The speaker driver of claim 8, 9, 10 or 11, **characterized** in that the control amplifier (13) is provided with a phase compensating circuit and a frequency characteristics compensating circuit in order to improve the characteristics of the speaker.

13. The speaker of anyone of claims 1 to 7, **characterized** in that the speaker is further provided with a velocity sensor and/or an acceleration sensor for detecting a velocity and/or an acceleration, respectively, of the moving body (5) or of another element associated with the moving body (5).

14. The speaker driver of any one of claims 8 to 12, **characterized** in that the speaker is further provided with a velocity sensor and/or an acceleration sensor for respectively detecting a velocity and/or an acceleration of the moving body (5) or another element associated with the moving body (5), and in that a detection signal from said velocity and/or acceleration sensor(s) is/are further supplied as feedback signals, in addition to the position signal from the position sensor, to said control amplifier (13) in order to improve its response and the center position holding function of said moving body (5) when no signal is present.

FIG.1

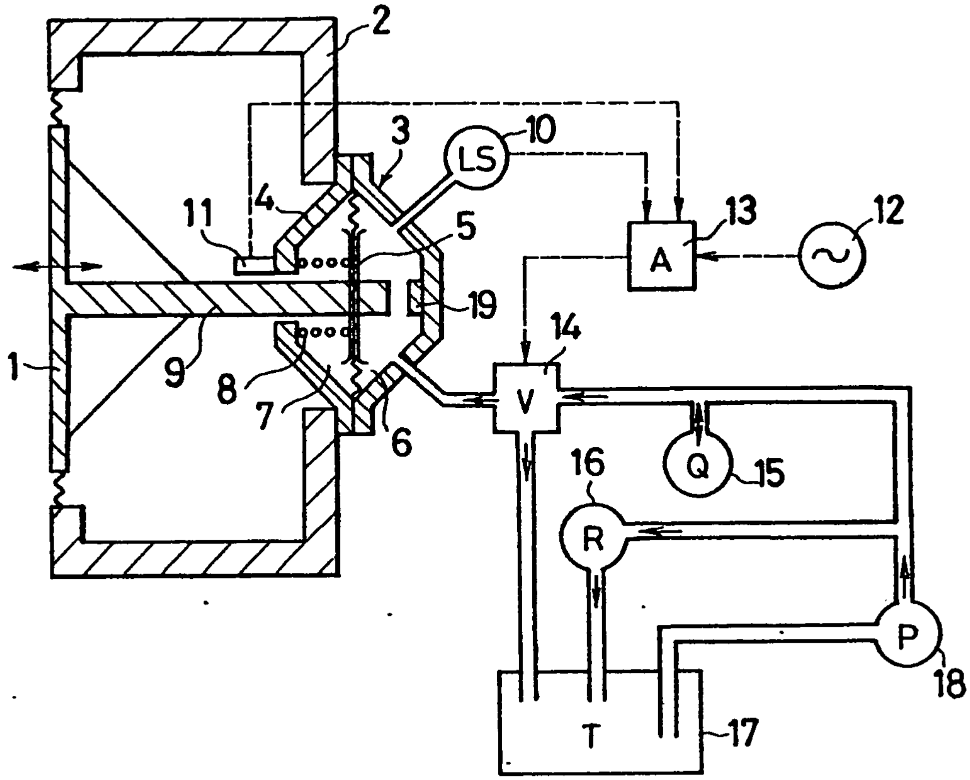
2
3
LS
10
13
12
A
11
4
5
19
14
V
1
9
8
7
6
16
Q
15
R
P
18
T
17

FIG.2

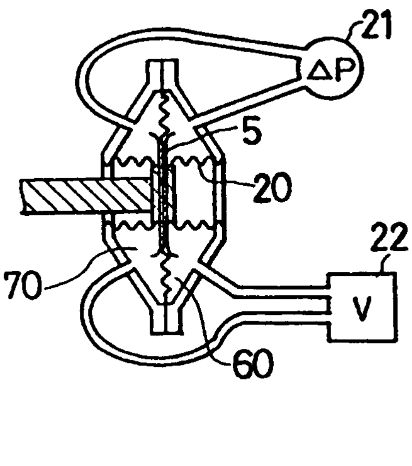
21
ΔP
5
20
22
70
V
60

FIG.3

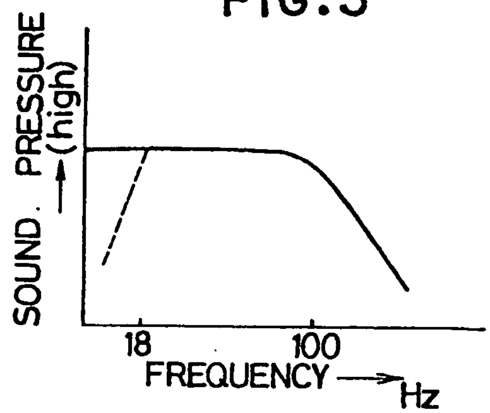

FIG.4

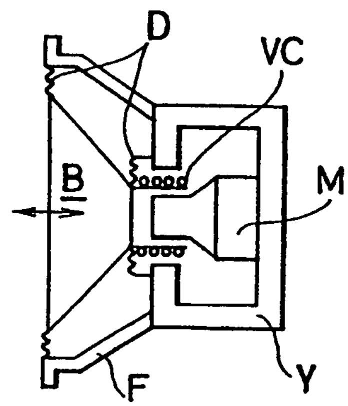

FIG.5